ON SOME ASPECTS OF VEGETABLE PATHOLOGY AND THE CONDITIONS WHICH INFLUENCE THE DISSEMINATION OF PLANT DISEASES.

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THE modern vegetable pathologist finds himself confronted at the very outset of his investigations by many preliminary questions which he is obliged to answer more or less satisfactorily before he can recommend with any degree of certainty a definite line of preventive or curative treatment.

He must be familiar with the main principles of vegetable physiology in general and the normal anatomy and histology of the special plant under consideration, in order that he may decide when and how the general course of the physiological activities of the plant is disturbed, and whether the structure which he observes is normal or otherwise. In case the anatomy is evidently morbid, he must be prepared to diagnose the case with as great a degree of accuracy as possible. Let us suppose that, as a result of extended observations upon one plant or a series of plants showing similar symptoms of disease, he finds that a particular organism is generally or constantly associated with the disease. I pass over the large class of cases in which no such organism is observed, and in which therefore the pathologist must put all his knowledge to the test, examine the environment with the utmost attention to detail, exhaust all his resources, and test every possible theory in his search for operative causes.

But, having found a possible connection between the diseased condition under observation and a living organism, the arduous portion of his work begins, viz., the determination of the parasitism or the mere saprophytism of the organism in question. For it is not enough merely to observe the association of a living organism of fungous or bacterial nature with the diseased condition, no matter how intimate or constant such association may be. Of course, there may be cases, such as the "black-knot" of plum trees, in which the effect of the fungus is so apparent and its parasitic nature so manifest that the evidence of the unaided eye is almost conclusive (though even in this case it will be remembered that for years the knots were supposed to be caused by insects), but in the vast majority of cases a far more searching proof is necessary. The organism whose parasitic nature is in question must be isolated from its host and grown in a pure culture; thence it must be transferred with due care to the uninjured tissues of a healthy plant of the same species as that from which it was derived, growing under normal conditions; in this plant it must produce symptoms of disease identical with those originally observed; and, finally, from this plant the same organism must again be isolated. Only under the fulfillment of such conditions can an organism be stamped as an absolute parasite.

These are rules made familiar to us by the methods of modern bacteriology, but they too seldom enter into the practice of the vegetable pathologist. It may be said in passing that their fulfillment cannot always be attained. It is more than probable that only an extremely small proportion of the diseases of plants which are commonly attributed to fungous parasites are absolutely parasitic in their nature—that is, due to organisms which can attack and penetrate the uninjured tissues of healthy plants growing under normal conditions, and live therein at the expense and to the detriment of the host. In most cases the pathologist must be prepared to search for injured tissues offering an opportunity for saprophytic, followed possibly by parasitic attacks, or for unfavorable surroundings weakening the plant or rendering it peculiarly susceptible to the attacks of semiparasitic organisms. Such conditions are easily induced, and great care has to be exercised in drawing conclusions from results obtained in the laboratory or greenhouse from inoculations of wounded tissues of plants kept under conditions of warmth and moisture which seldom, if ever, obtain in the field. The pathologist must be prepared to ascertain and to correct the predisposing as well as the apparent causes of disease, and among such causes he may even be forced to include the long process of artificial selection which has had as its almost exclusive aim the development of plants along lines of fruitage only, with too little regard to those factors which tend to produce hardy stock resistant to unfavorable conditions.

I make these statements with some hesitation, yet I believe them to be borne out by facts. It is becoming more and more apparent that in combating the host of fungi which invade our orchards and truck farms in these days of intensive farming, due regard must be paid to what we may call the hygiene of plant life. The proper regulation of the water supply by drainage and tillage; the securing of the free access of air and sunlight by pruning, thinning, and training; care in the selection of healthy, resistant stock; the intelligent use of fertilizers and their adaptation to the needs of the plant—these are some of the sanitary measures which, duly considered and acted upon, will do more than the mere use of fungicides to insure success in dealing with fungous diseases.

To take individual proofs of these general statements: Experiments recently conducted at the Rhode Island Experiment Station have gone far to show that the two most serious diseases of celery are due, not primarily to the attacks of the fungi associated with them, though both of them might properly be placed among Sorauer's "Schwäche-Parasiten," but to a weakening of the plants attributable to the purely artificial level method of culture whereby the roots are exposed to all the temperature-changes of the surface soil. A mulch, consisting even of the leaves of diseased celery teeming with the spores of the fungi in question, served to prevent the spread of the disease. That proper attention to purely cultural conditions will very largely decrease the prevalence of apple "scab" is a matter of common observation, and I have myself seen a peach orchard, showing the first symptons of a serious attack of *Cercospora Persica*, completely restored to health by tillage and a judicious application of nitrate of soda. I would direct the attention of every vegetable pathologist to the words in which Professor Bailey summarizes one of his bulletins on the care of orchards, and to the order of the terms which he uses, "Till, feed, prune, spray." I have outlined the steps which the vegetable pathologist must take in order to secure a trustworthy diagnosis. Having learned to distinguish a morbid condition through a working acquaintanceship with normal physiology and anatomy, he must determine the final cause of disease; by careful investigation he must decide whether it is parasitic or otherwise, and, if so, in what degree; and he must determine whether the attack of the parasite is immediate, or superinduced by the local destruction of tissues or by the general debility of the plant.

One very important question remains to be considered, viz., When and how the parasite, if such it be, secures entrance to the host and is thence disseminated. Upon the answer to this question depends in great measure the whole philosophy of preventive treatment. One method of determining the matter is, of course, the careful study of the life history of the fungus in question. If it be known, with a reasonable degree of certainty, that a certain pathogenic fungus depends largely upon aerial summer-spores for its dissemination, we naturally recommend preventive treatment with fungicides; if it is a perennial mycelium to which the fungus owes its continuous vitality, we are prepared to advise pruning. If it is ascertained that certain spores, seemingly delicate, are enabled to pass uninjured through an animal's digestive tract, the manure heap demands our first attention; and if careful research in the field and the laboratory is at length rewarded by the discovery of resistant spores produced during the winter in or upon the refuse of a diseased crop, we very properly lay the utmost stress upon a thorough clearing up and destruction of all such refuse. A knowledge of such facts connected with parasitic fungi is absolutely essential to any intelligent application of preventive measures, and we cannot value too highly such researches as those of Thaxter upon "potato-scab," or of Aderhold upon the ascosporic forms of *Fusi-*

cladium dendriticum, and *F. pyrinum*. But fruitful results are also to be obtained by observations upon the direct means by which the reproductive bodies of parasitic fungi are borne hither and thither and become fresh sources of contagion.

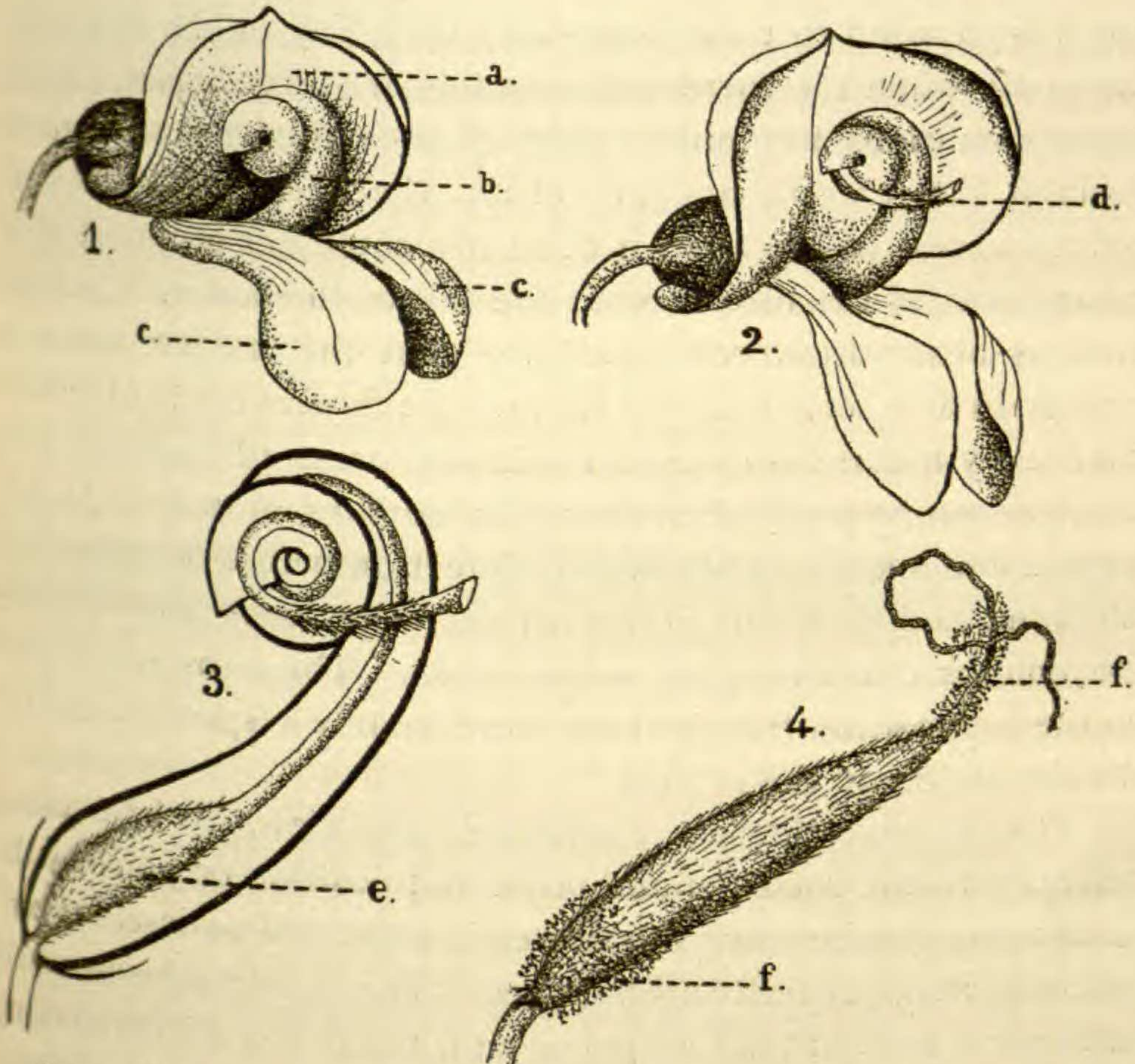

FIG. 1.—Normal flower of lima bean.
FIG. 2.—The same, with wing-petals depressed and style protruded.
FIG. 3.—Section of keel, showing the ovary and protruded style.
FIG. 4.—Young pod, showing mildew at the two extremities.

This leads me to speak of a rather striking case which came under my observation during the past summer. For several years the growers of lima beans in southern Connecticut have suffered great losses through the destructive attacks of the mildew, *Phytophthora Phaseoli* Thaxter. This fungus attacks the pods, sometimes covering them with its white, felt-like mycelium ; it also occurs upon the leaves, though rarely and inconspicuously, and upon the fruiting branches where it does extensive injury by destroying the tissues below the flowers, thus causing the death of all the young pods above the point of attack. Before proceeding farther let us recall the structure of the bean flower. It will be remembered that the pistil and the stamens are completely enclosed in the spirally coiled keel (*fig. 1*). No portion of them is exposed to view except the very base of the ovary, and that only when the surrounding petals are forced apart. Under these conditions not only would close-fertilization seem to be assured, but it would appear certain that, however the mildew gained access to the host, it certainly could not be by infection of any part of the pistil before the fall of the flower. Yet, continuous observation convinced me that the mildew failed to appear to any serious degree before the flowers began to expand, that fairly mature pods seldom showed areas of fresh infection, that the young pods often showed a copious growth of fruiting hyphæ and spores indicative of infection before the fall of the blossom, and that the points of infection were always at the extreme base or tip of the young pods. These observations led to the supposition that insects were mainly responsible for the dissemination of the mildew.

Further investigation confirmed this view. I have called attention to the enclosed and protected position occupied by the pistil; this obtains until the flower is visited by an insect of considerable size, generally a honeybee. The projecting wing-petals offer a convenient landing place, and, as the bee alights on them, his weight deflects both wings and keel, the style is protruded from the keel, the bee's abdomen brushes over it, and in his efforts to reach the bottom of the flower the petals are forced apart, the base of the ovary exposed and the bee's head comes in contact with it (*figs. 2, 3*). Thus cross-fertilization is secured, but if the bee has, by chance, touched a mildewed pod with either head or abdomen, fungous infection no less surely occurs. It will be noted that the only portions of the pistil touched by the bee are the base of the ovary and the style. An examination of scores of flowers showed that in the majority of cases they were infected, and in these cases, without exception, the points of infection were identical with the spots touched by the bees (*fig. 4*). One additional point might be mentioned. On a very badly diseased plantation it was noticeable that the spread of the mildew practically ceased about September 10, although the vines continued to flower and produce pods until October. I am at a loss to account for this sudden cessation of fungous activity, but it is worthy of notice in this connection that after the date above mentioned hardly any bees were seen in the plantation.

It seems almost certain then, that in the case of this mildew at least, insects are the principal agents in the dissemination of the fungus.

But I have already stated that the fungus sometimes appears elsewhere than upon the young pods. In some cases it is apparent from the respective positions of old and fresh points of infection upon the leaves or mature pods that the spores have been carried by the rain or dripping dew from one portion of the vine to a subjacent one, but certain facts led me to think that the wind played a considerable part in the infection of older tissues. In order to test this matter I pursued the following course. The mildew is usually confined to comparatively low, damp situations. The grounds of the Connecticut Experiment Station occupy an elevated position, the land is well drained, the soil light and sandy, and so far as I know, lima beans on this land have never mildewed. During the past summer they occupied two rows running east and west. Directly south of them, at a distance of about 100 feet, were two rows of bush limas running north and south (*fig. 5*). On August 14, when the mildew had been abundant for a month or more on a farm at a distance of about a mile in a straight line from the Station, the Station vines were carefully examined and found to be perfectly free from mildew. The following day two mildewed pods were brought from the farm above mentioned, and the mildewed surface of one of them was rubbed upon a single healthy and almost mature pod at the east end of each row of pole limas. The prevailing winds at the time and for the ten succeeding days varied from northwest to northeast. Within a week the mildew appeared abundantly upon the two infected pods and from this point swept down both rows from east to west, and in two weeks the crop was practically ruined. Meantime the two rows of bush limas were examined daily. About ten days after the first infection of the pole limas, mildewed pods were found upon the bush limas, but only at the north end of the

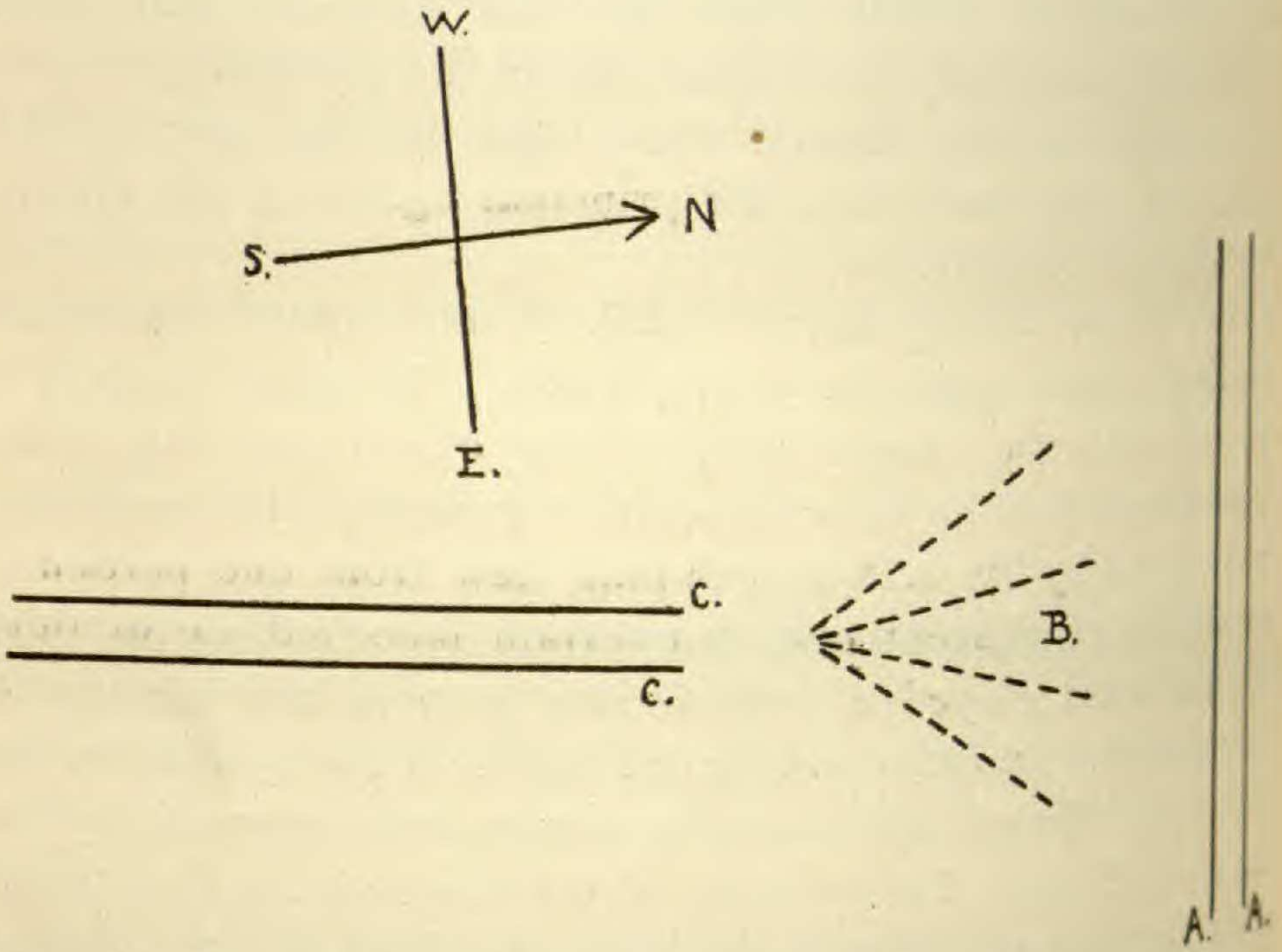

FIG. 5.—*A*, *A*, points of primary artificial infection on pole beans; *B*, course of prevailing winds; *C*, *C*, points of secondary natural infection on bush beans.

rows nearest to the source of infection. From this point it spread rapidly southward until both rows were completely involved.

The conclusion seems inevitable that not only do insects play an important part in the dissemination of fungous diseases, but that the wind certainly does its share.

How this particular fungus is propagated from season to season is a question of great importance, but it is apart from the object of the present paper which is to call renewed attention to the divers lines along which the vegetable pathologist is obliged to direct his attention, and the importance and interest which attaches to all observations relative to the dissemination of fungous diseases.

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